EFFECT OF NITROGEN AND SEASON ON THE YIELD, PROTEIN, AND AMINO ACID CONTENTS OF TWO HAWAIIAN CORN VARIETIES

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INTRODUCTION

Although much attention has been given to the effects of nitrogen (N) fertilization and season on corn growth, yield and quality in the temperate zones, there has been, to date, little work done on these interactions in the tropics. On the other hand, interest in growing forage and grain crops in Hawaii and the tropics has been increasing. In Hawaii, this interest stems from a desire for agricultural self-sufficiency, while in the tropics, the desire is to help Third World or less developed countries achieve self-sufficiency in the production of food and feed grains. Information on N and seasonal interactions would permit farmers to make decisions on optimum levels of N for a given growing season, with the expectation that lower insolation during the winter season would reduce the N requirement as a result of less vigorous crop growth. This study was undertaken, therefore, to obtain data on the interactions between N fertilization and planting date on the growth and yield of two Hawaiian corn varieties. It was a further objective to evaluate the effects, if any, of N, season and variety on the nutritional quality of the grain as measured by total protein and soluble and total amino acid contents.

LITERATURE REVIEW

Effect of N Fertilization on the Growth and Yield of Corn

Chemical elements which are necessary for the growth and reproduction of most plants are termed "essential elements." Essential elements are categorized as micronutrients or macronutrients, depending on the quantity in which they are required. Iron (FE), Molybdenum (Mo), Boron (B), Copper (Cu), Manganese (Mn), Zinc (Zn) and Chlorine (Cl) are required in relatively small amounts (about 0.1 to 100 ppm) and are considered to be trace elements or micronutrients. The macronutrients are required in larger quantities and include Carbon (C), Hydrogen (H), Oxygen (O), Phosphorus (P), Potassium (K), Sulfur (S), Calcium (Ca), Magnesium (Mg) and Nitrogen (N). Some essential elements are components of cellular molecules (i.e., proteins, chlorophyll), whereas others appear to be necessary for enzyme activity, although they are not part of the enzyme molecule itself (activators). Lack of any of the essential elements generally results in reduced growth, abnormalities or death of the plant.

Of the essential nutrients, N is the most limiting element in corn production on the majority of soils throughout the world (Shukla, 1972; Olson et al., 1976). For this reason, the trend in U.S. agricultural practice has been towards increased yield through higher fertility. Thomas (1956), Colyer and Kroth (1968), Gonske and Keeney (1969) and Perry and Olson (1975) found that the total dry matter yield of corn increased significantly with increased N fertilization until an optimum was reached. Nunez and Kamprath (1969) obtained highest grain yields at an N application rate of 280 kg per ha. Similarly, Golingai (1972) found that yield and protein content of sorghum, which was grown at Waimanalo Experimental Station, increased as N application was increased from 100 to 300 lb/ac (112.08 kg/ha to 336.25 kg/ha).

Nunez and Kamprath (1969) reported that increasing N rates from 112 to 280 kg/ha had no effect on leaf area per plant or the leaf area index (LAI), but that efficiency of a given leaf area to produce grain was higher as N rates were increased.

Zuber et al. (1954) concluded that corn yield was influenced less by variety than plant population or N level.

Effect of N Fertilization on the Nutritional Quality of Corn

The effect of N fertilization on corn extends beyond its effects on yield alone. The nutritional quality of both the stover and grain have also been shown to be altered by added N.

Gonske and Keeney (1969) reported that the total N content of corn stalks and leaves increased significantly with increased applications of N, with up to two-fold increases at a rate of 300 kg/ha. Younis and Agabauri (1967) found that in the case of sorghum stover, protein N, as a percentage of total N, decreased as the level of N was increased.

Unfavorable effects of added N were reported by Gonske and Keeney (1969). They found that application of excess amounts of fertilizer N resulted in the accumulation of deleterious soluble N compounds in silage corn. NO_3 - N levels increased as fertilizer N was increased from 100 kg/ha to 200 kg/ha to 300 kg/ha, the increase being more marked above 200 kg/ha. They also found that late dent corn had higher dry matter and protein yields and lower NO_3 - N and soluble N compounds than early dent corn.

East and Jones (1920) reported that the average protein content of water-free material is 8.2 - 13.8%, the average being 11.5% in the grain of dent corn. Zein comprises about 50% of the total protein of corn, but is very low in the essential amino acids lysine and tryptophane, and contains relatively small amounts of arginine and histidine; therefore, some other source of additional protein must be supplied if it is to be used as feed for monogastric animals.

Sauberlich et al. (1953) found that the rate of N fertilization and the variety used greatly influenced the protein content of corn grain. Prince (1954) demonstrated a direct relationship between the rate of N application and crude protein content. Waggle et al. (1967), however, reported that protein N, as a percentage of total N in sorghum grain, decreased as N level was increased. Frey (1951), Deckard et al. (1973) and Johnson and Lay (1974) reported that percent protein of corn grain increased significantly as N level was increased, regardless of time of application, but that grain yields did not increase significantly.

Schneider et al. (1952) dissected the kernels from six strains of corn into tip cap, hull, germ and endosperm. Percent N of the parts was in the decreasing order of germ, endosperm, hull and tip cap. N of the kernel parts were separated into five solubility fractions. It was discovered that all N fractions increased as a result of increased total N, which, in turn, resulted from N fertilization. Zein, a low quality protein, was present in the greatest amounts. Schneider et al. therefore concluded that the protein of high protein corn had a lower biological value than the protein of low protein corn.

Doty et al. (1946) grew 28 corn single crosses and analyzed the grains for total protein, tyrosine, tryptophane, cystine, arginine and histidine. They found that the amount of the various amino acids in corn protein was genetically determined. This effect was believed to be on the protein, and not necessarily correlated with total protein content, since amino acid contents were expressed on a per unit N basis. Sauberlich (1953) reported that as the percentage of protein in corn increased as N level was increased from 24 lb/ac to 84 lb/ac (26.91 kg/ha to 94.15 kg/ha), the amino acid content of corn grains increased. Sonntag and Michael (1973) compared the influence of N on the protein content and composition of high lysine and conventional forms of corn. Increased N fertilization resulted in a slight reduction of percent lysine in the crude protein of conventional cultivars; in the mutants, it was unchanged or only slightly increased. The prolamine/glutelin ratio was about 2 : 1 whereas in the mutants it was 1 : 1 (glutelin is lysine- and tryptophane-rich protein).

Effect of Climate and Season on Growth and Yield of Corn

Hawaii is the only one of the 50 states which is completely surrounded by the ocean and is within the tropics. For these reasons, climate and season in Hawaii have a vastly different meaning from that of the temperate regions. A comparison of conditions in Hawaii and temperate zone cities is shown in Table 1. The small variations in length of daylight and the smaller annual variations in the altitude of the sun above the horizon in Hawaii as compared with the other states was explained by Blumenstock and Price (1974) as resulting in

Table 1

Daylengths at Various U.S. Cities

Cities	North Latitude	Longest Day (In hours and minutes - to nearest 10 min.)				Shortest Day			
		Without Twilight		Including Twilight		Without Twilight		Including Twilight	
		Hrs.	Min.	Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Anchorage	61°	19	20	24		5	30	7	30
Seattle	48°	16	0	17	20	8	20	9	30
St. Louis; Washington, D.C.	39°	15	0	16	0	9	20	10	20
Los Angeles; Atlanta	34°	14	30	15	30	9	50	10	50
Brownsville; Miami	26°	13	40	14	30	10	30	11	20
HONOLULU	21°	13	20	14	10	10	50	11	40

Source: Blumenstock, D.I. and S. Price (1974) the slight changes in incoming solar radiation with time of year. The slight seasonal changes in temperature in Hawaii were attributed to the steady flow of ocean air over the islands and to the relatively constant levels of incoming solar radiation throughout the year.

The topography of the islands play a great role in the climate of Hawaii also. Blumenstock and Price (1974) commented that "If the islands of the State of Hawaii did not exist, the average rainfall upon the water where the islands actually lie would be about 25 inches. Thus the islands extract from the air that passes across them about 45 inches of rainfall that otherwise would not fall. . . the mountains are dominantly responsible for this added bonus. . . ."

Windspeeds vary throughout the islands but are mainly from the northeast (trade winds) during the summer months. In the winter months they are less prevalent; major storms frequently occur at this time, with winds blowing from any direction.

In general, windward areas of the islands are cloudier than the leeward areas, with a corresponding decrease in solar radiation in these areas.

That differences in environment lead to differences in growth and yield of corn was demonstrated. The effects of temperature on corn seedling growth rate was studied by Winter and Pendleton (1970). They found that the optimum air temperature for seedling growth was 33.5 C. Alofe et al. (1973) grew sixteen corn varieties under constant day temperatures (35 C) and variable night temperatures and found that growth was fastest at a night temperature of 24 C. Winter and Pendleton (1970) found that for plants in a radiation-rich environment, cooling with water mist when the midday air temperature was greater than 29.4 C resulted in reduced yield. Benoit et al. (1965) also reported that low temperatures resulted in decreased yield, especially during the ear formation period. On the other hand, Peters et al. (1971) reported a 40% decrease in yield of corn grain (from 10,168 kg/ha to 6,277 kg/ha) when average night temperature was increased from 16.6 C to 29.4 C.

Coligado and Brown (1975) studied the effects of temperature on tassel initiation. They found that time to tassel initiation decreased consistently as temperature was increased from 15 C to 25 C. However, temperatures beyond 35 C had no effect. Runge (1968) showed that the maximum effect of temperature and rainfall on corn yield was from 25 days before to 15 days after anthesis. High temperatures (maximum daily temperatures between 32.2 and 37.8 C) increased corn yield when adequate moisture was available.

Both photoperiod and solar insolation affect rates of corn plant development and final yield. Villanueva (1971) reported changes in both tasseling and silking dates with changing season. Bodke (1969) and Duncan and Hesketh (1968) showed that corn yield (number of ears per plant and weight per ear) increased with higher sunlight. The effect of sunlight on yield was shown to be due to high photosynthetic rates which prevailed at high light levels. In studies involving corn planted at locations with similar latitude and elevation but different climates, Duncan et al. (1973) reported that grain yields per hectare were highest at the location with the highest daily insolation, highest daylight temperatures and second lowest night temperatures. Early et al.

(1967) found that grain production was greatly reduced by shade treatments, and that shading during the reproductive phase was most detrimental. Stover production also decreased as light was decreased during the vegetative period.

Andrew et al. (1956), in a study of climate on corn, found that uniform rainfall aided in increasing yield, in part, by lowering the incidence of plant disease. Villanueva (1971) studied the effects of season on a number of corn varieties at different areas in Hawaii. At Waimanalo Experimental Station, at a plant population of 54,340 per ha and at an N rate of 224 kg/ha, he found that plant height, ear height and ear length were reduced as date of planting was delayed from May to July to September. Stover and ear yields tended to be reduced also as planting date was delayed.

Effect of Climate and Season on Nutritional Quality of Corn

East and Jones (1920) stated that external factors, or environment, had a marked effect on the protein content of corn. They further stated that the protein content may be altered by 40% from the amount produced under normal growing conditions.

Hageman et al. (1961) found that a reduction in light intensity due to either artificial or competitive plant shading was associated with reduced nitrate reductase activity in corn. High nitrate reductase activity was positively correlated with water soluble protein content, and plants which were widely spaced or exposed to sunlight had the highest enzyme activity and protein (water soluble) and nitrate content.

Early et al. (1966), in their study of the effects of shade on corn, reported that total plant (grain and stover) protein decreased linearly with increasing shade. The effect was observed with as little as a 30% decrease in light.

Qureshi and Bray (1973) found that plants which were irrigated every week had less protein than those irrigated at two, three or four week intervals. However, total yields of protein were higher for the treatment which was irrigated weekly because of the higher total forage yield.

MATERIALS AND METHODS

The effects of N and season on grain and stover production by two varieties of corn (Zea mays L.) were studied in a field experiment conducted at the University of Hawaii's Waimanalo Experimental Station. The soil at that site is characterized as very fine, kaolinitic, isohypothermic, Isotypic Haplustoll family, and belongs to the Waialua series.

The experimental design was a randomized complete block with a factorial arrangement of the treatments. The experimental treatments consisted of four planting dates, three N levels and two corn varieties with four replications. The dates of planting were June 16, 1970, October 14, 1970, February 23, 1971 and June 10, 1971. Nitrogen levels were 112, 224 and 448 kg per ha in the form of ammonium nitrate, half of which was broadcast at planting with the balance applied as a side-dressing approximately four weeks after planting. Corn varieties tested were Helminthosporium Resistant Composite by Hawaiian Yellow (HRC x HY) and Waimea Dent (WD). Helminthosporium Resistant Composite is an introduction resulting from the Rockefeller Program in Mexico, which has good resistance to the northern corn leaf blight (H. turcicum). Hawaiian Yellow was bred and developed in Hawaii of flint and dent parents. Waimea Dent, primarily a dent corn, was developed in Hawaii through selection and also has good resistance to H. turcicum.

The experimental area was 0.1 ha and two such adjacent areas were required to properly space the four plantings through the year. Prior to planting, the soil was rototilled. At that time, phosphorus in the form of triple-superphosphate and potassium in the form of muriate of potash were incorporated into the soil at rates of 282 and 224 kg per ha, respectively. A border of sweet corn was planted around the experimental area to serve as a windbreak. Subplots of 0.0028 ha each were then marked off for each treatment.

Each subplot contained six rows 5.94 m in length, with 76 cm between rows. Three seeds were planted per hill with 46 cm between hills. After emergence, approximately three weeks after planting, the plants were thinned to two per hill to give a total plant population of about 57,407 plants per ha. All data were collected from the middle two rows of each subplot, omitting two hills at each end of the two rows; this area constituted 6.271 m^2. Assuming 100% germination and growth of seeds, the maximum number of plants per subplot was thirty-six.

Adequate moisture levels were maintained by periodic sprinkler irrigation. Control of weeds was accomplished by a preplant application of atrazine at a rate of 2 kg per ha. Control of insects was maintained by periodic application of "Cygon" and "Malathion" at the rate of 2.5 lbs. per 100 gallons of water.

Meteorological data were collected daily at Waimanalo Experimental Station from June 1970 through October 1971. Data included rainfall, maximum and minimum temperatures and solar radiation, measured by a rain gauge, maximum-minimum thermometers and an actinometer, respectively.

As the time of flowering approached, data on the number of days to 50% tasseling and silking were collected for all treatments by counting the number of plants having emerged tassels and silks every other day.

The height from the soil line to the base of the highest ear was measured prior to harvesting. At harvest, stalks were cut off at the soil line and the ears were separated from the stalks for the measurement of stover, ear and grain weights.

All plant materials were oven-dried to a constant weight at about 65 C in a forced-draft oven. Estimated yield data included a correction for missing stalks (Dr. J.L. Brewbaker, personal communication), which was computed in the following manner:

$$\frac{\text{Weight of component (kg)}}{\text{Number of stalks harvested/subplot}} \times 36 \text{ (potential number)}$$

These data were then converted to yield per ha.

After the ears were husked and weighed, they were completely shelled. The 1000 grain weight for each treatment was calculated by multiplying the weight of 100 randomly selected kernels by 10.

The effect of treatment on total protein and amino acid compliment of the grain was evaluated for each season. A random sample of grains was taken from each subplot for the determination of total N and soluble and total amino acids. The samples were ground to 40 mesh in a Wiley mill and stored in plastic vials until analyses could be made. Total N was determined by the macro-Kjeldahl procedure (Association of Official Agricultural Chemists, 1960). Crude protein content of the grain was calculated by multiplying the percent total N by 6.25.

Soluble amino acid content was determined by using the Technicon amino acid analyzer. A 15 gm sample was first defatted with 75 ml hexanes. Soluble amino acids were extracted by washing the sample with

200 ml of 75% ethyl alcohol. The extract was filtered using Whatman no. 42 paper and diluted to 250 ml. The filtrate was evaporated to a volume of about 15 ml at 38 C in a flash evaporator, transferred to a 25 ml volumetric flask and made to volume with distilled water. A 4 ml aliquot was transferred to a 5 ml volumetric flask, 0.083 ml 6 N HCl was added, and the flask was brought to volume with distilled water. This mixture was filtered through Whatman no. 42 filter paper and 3 ml of the filtrate was mixed with 1.0 ml 62.5% sucrose and 0.25 ml 2.5 mM norleucine (internal standard). After diluting the mixture to 5 ml, 2 ml were transferred to the ion-exchange column and analyzed on the Technicon analyzer in a 16 hr overnight run.

Due to the presence of the amides asparagine and glutamine, which have elution times close to threonine and serine, it was necessary to make separate analyses of hydrolyzed samples. A 3 ml aliquot was hydrolyzed using 0.6 ml 6 N HCl for 1 hr in a boiling water bath. After cooling, 0.5 ml 6 N NaOH was added to a 5 ml volumetric flask, which was then made to volume with distilled water and mixed. The mixture was filtered through Whatman no. 42 paper. A 2 ml aliquot was placed on the ion-exchange column and a 4 hr run was made to determine threonine and serine as well as the hydrolyzed amides.

Total amino acid content of selected samples was determined following the method of Bandemer and Evans (1963). A 2.5 g ground sample was defatted using 12.5 ml hexanes. After removal of the hexanes by filtering through Whatman no. 42 filter paper, the sample was hydrolyzed in an autoclave for 6 hr at 15 lb pressure using 50 ml 20% HCl. The HCl was then removed from the hydrolyzate by an alternating process of dilution with distilled water and evaporation to near dryness in a steam bath. The hydrolyzate was dissolved in 100 ml distilled water and diluted to 250 ml. The sample was then treated in a similar manner to soluble amino acid samples, using the Technicon amino acid analyzer.

Analysis of variance (Snedecor and Cochran, 1969) of experimental data was conducted using a programmable calculator.

RESULTS AND DISCUSSION

The effects of three N levels on the growth, yield and nutritional quality of two Hawaiian corn varieties were studied at four planting dates. The four plantings, spaced approximately four months apart, were grown under varying meteorological conditions. Monthly rainfall, average monthly maximum and minimum temperatures and solar radiation at Waimanalo Experimental Station from June 1970 through October 1971 are presented in Table 2.

The planting made on June 16, 1970 and harvested on October 15, 1970 (Crop I) was exposed to conditions of relatively little rainfall (99.4 mm) and the highest temperatures of any of the plantings (Table 3). Solar radiation for the June 1970 planting was nearly as high as that of the growing period which began on June 10, 1971. Maximum temperatures for the October and February plantings were 2 to 3 C below those of the June planting while minimum temperatures for the winter season were about 2 C below summer temperatures. The highest rainfall of the season (1,250.4 mm) fell during the October 14, 1970 to February 23, 1971 crop (Crop II). Heavy thunderstorms dropped 549.9 mm of rain in November alone. (From 1919 to 1972, except for 1952, 1953 and 1954 when no data were available, the only higher precipitation recorded for the month of November was in 1965 when 597.9 mm was measured. The next highest rainfall (322.1 mm) occurred in 1966. Average rainfall for November 1919 - 1972 is 115.8 mm (U.S. Environmental Data Service Climatological Data. Hawaii and Pacific). In December a wide variety of winter weather was displayed in Hawaii: intense rains (dropping 616.7 mm of rain), high swells and surf and high winds. Gale warnings

Table 2. -- Monthly Rainfall, Temperature and Solar Radiation Data Collected at Waimanalo Experimental Station from June 1970 to October 1971

Month	Total Rainfall	Average Monthly Temperature (C)		Average Solar Radiation
	(mm)	Maximum	Minimum	(gm-cal cm^{-2}/day^{-1})
June 1970	12.7	28.4	22.4	461
July	48.0	29.0	22.3	462
August	32.0	29.7	22.5	465
September	25.9	29.8	22.2	480
October	119.9	28.5	22.2	315
November	549.9	26.7	20.4	232
December	616.7	25.7	20.8	222
January 1971	311.4	24.8	17.2	213
February	64.5	26.7	18.4	343
March	67.3	26.0	19.8	---[a]
April	80.5	26.4	20.5	367
May	24.9	27.5	21.5	465
June	106.4	27.8	21.2	473
July	11.7	28.5	22.1	493
August	48.5	29.2	22.1	483
September	58.4	29.4	22.3	---[a]
October	64.3	28.6	21.9	---[a]

[a] Instrument inoperative

Table 3

Average Climatic Data for the Period From Date of Planting to 90 Days[a] After Planting

Planting Date	Mean Temperature (C)		Solar Radiation	Total Rainfall
	Maximum	Minimum	(gm-cal cm^{-2}/day^{-1})	(mm)
June 16, 1970	29.2	22.4	427	99.4
October 14, 1970	26.4	20.2	250	1,250.4
February 23, 1971	26.7	20.1	304[b]	164.1
June 10, 1971	28.7	21.9	492	177.8

[a] Solar radiation data for the June 10 planting date is for an 82 day period because the instrument became inoperative.

[b] Radiation data for this period was based on estimated solar radiation for the month of March, which was calculated by averaging the data for February and April.

were in effect on 21 days, and at Honolulu Airport the tradewinds had a frequency of 97% as compared with the December average of 60%. From December 25 - 29, very strong northeasterly tradewinds with gusts of 50 - 60 m.p.h. caused widespread damage. The unusually harsh winds and heavy rainfall during the tasseling and silking stages and near harvesting resulted in lodging, breakage and decomposition of plants in the field. Consequently, some data were unobtainable. The growing season for this period was characterized by the lowest solar radiation of the season and relatively low temperatures also prevailed.

Rainfall during the February 1971 planting was moderate (164.1 mm) relative to the sparse rain for the June 1970 crop and abundant rainfall of the October planting. Plants of Crop III, which were harvested on June 28, 1971, were exposed to increasing daylength, solar radiation and temperatures.

The seasonal conditions under which the June 1971 crop (Crop IV) was grown essentially duplicated those of the previous year, except that rainfall was about 79 mm higher (Table 3). Solar radiation was higher for this planting than for the other crops. The crop was harvested on October 5, 1971.

Effect of Variety, Nitrogen and Their Interactions on Corn Growth and Yield

Crop I

Crop I was planted on June 16, 1970 and harvested on October 15, 1970. Days to 50% tasseling, stalk height, stover yield and total dry matter yield of the first planting were not influenced significantly by any of the treatments (Appendix A, E). However, the varieties were significantly different with regard to number of days to 50% silking, unhusked and husked ear yields and shelled grain weight (Table 4, Appendix E). WD reached mid-silk about two days sooner than HRC x HY. Furthermore, the unhusked and husked ear yields and shelled grain yield of WD were 29%, 33% and 33% greater, respectively, than those of HRC x HY. Unhusked ear, husked ear, shelled grain and total dry matter yields of WD decreased as N level was increased. However, the differences were non-significant. The unhusked ear, husked ear and shelled grain yields of HRC x HY similarly declined as N level was increased, although the trend was non-significant. The consistent trend of yield with increasing N for both varieties suggests that the higher levels of N may have stimulated vegetative growth to the detriment of yield. The lack of any significant yield response to N suggests that residual N in the soil was quite high.

Crop II

This crop was planted on October 14, 1970 and harvested on February 23, 1971. None of the treatments significantly influenced tasseling (Appendix F). The 50% tasseling stage was reached in 67 - 68 days after planting, on December 20 - 21, by both varieties (Appendix

Table 4

Effects of Variety on Aspects of Crop Development and Yield[a]

(June 1970 - October 1970)

	Variety[b]	
	WD	HRC x HY
Days to 50% Silking	64	66
Unhusked Ear Yield (kg/subplot)	5.76	4.09
Husked Ear Yield (kg/subplot)	4.82	3.25
Shelled Grain Yield (kg/subplot)	3.94	2.63

[a] Values were averaged over three N levels.

[b] All parameters were significantly different at the 0.05 level of probability.

B). While the two varieties did not differ significantly with regard to days to 50% tasseling, there was a highly significant varietal difference in number of days to 50% silking. The varieties also differed significantly with regard to stover yield and unhusked ear yield (Table 5, Appendix F). As in the previous planting, the mid-point in silking was reached by WD approximately one week before its single-cross counterpart. High winds occurred on December 26 - 29, and diminished on December 30; this resulted in some lodging of stalks. By this time, WD had barely passed the 50% silking stage, and HRC x HY was not yet at that point. Lodging of stalks, and with them, silking cobs, may have exaggerated the differences in days to 50% silking between the two varieties. The data revealed a trend of an increase in the number of days to mid-silk with increased N, especially in the case of HRC x HY. This may have been due to increased vegetative growth and succulence promoted by increased levels of N, with a resultant delay in reproductive growth. However, the differences were not significant. The V x N interaction also was not significant.

The stover yield of HRC x HY was very significantly higher than that of WD for this planting (Table 5). The effects of N and the V x N interaction were non-significant.

Contrary to the stover yields, WD produced a significantly greater unhusked ear yield than HRC x HY (Table 5, Appendix F). Ear yields for both varieties tended to decrease with increasing N fertilization, but this treatment effect was not significant. The V x N interaction also was not significant.

Stalk height measurements were normally taken immediately prior

Table 5

Effects of Variety on Aspects of Crop Development and Yield[a]

(October 1970 - February 1971)

	Variety[b]	
	WD	HRC x HY
Days to 50% Silking	71	78
Stover Yield (kg/subplot)	2.31	3.32
Unhusked Ear Yield (kg/subplot)	1.11	0.32
Husked Ear Yield (kg/subplot)	0.97	0.28
Shelled Grain Yield (kg/subplot)	0.57[c]	0.20[c]
1000 Grain Weight (gm)	236.91[c]	292.21[c]

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[a] Values were averaged over three N levels.

[b] All varietal means were significantly different at at least the 0.05 level of probability.

[c] Values were averaged over two rather than three levels of N.

to harvest. However, in addition to the high winds of December 26 - 29, heavy rainstorms resulting in about 616 mm of rain during the month of December alone caused extensive lodging of plants in the field. The rainfall for December exceeded that of any other month in the growing season. (The average monthly rainfall for December between 1919 and 1971 was 159 mm). This prevented the measurement of stalk heights; hence, data were not available for this planting.

Total dry matter was not significantly affected by any of the treatments (Appendix F).

In three of the four replications at the highest N level, HRC x HY produced ears approximately 10 - 18 cm in length which were seedless. The cobs were vestigial nubs barely long enough for the attachment of the husks. The lack of significant reproductive development at the highest level of N suggests that vegetative growth at the highest N level was promoted to the point where interplant competition precluded normal development of the reproductive structures. As a result of the unavailability of data, analysis of variance tables were constructed in a manner different from the previous tables. The entire treatment of HRC x HY at the 448 kg/ha N level was dropped and the two varieties studied first separately, then jointly (Appendix F). Separate analyses of yields of WD and HRC x HY revealed no significant treatment effects on husked ear yields, shelled grain yield or 1000 grain weight. However, the combined analyses of the two varieties at the two lower N levels (112 and 224 kg/ha) showed that the husked ear and shelled grain yields produced by WD were significantly greater than those produced by HRC x HY (Table 5). N application and the

V x N interaction were not significant.

There was a significant varietal difference in the combined analysis of the 1000 grain weight (Table 5, Appendix F). On the basis of grain weights at the two lower N levels (112 and 224 kg/ha N), the kernels of HRC x HY were much heavier than those of WD. The effects of N and the V x N interaction were not significant. The significantly higher grain yield for WD with a significantly lower 1000 grain weight shows that many more WD than HRC x HY kernels were pollinated per plot.

The unhusked ear, husked ear, shelled grain and total dry matter yields decreased and the 1000 grain weight of WD increased as N level was increased; however, none of the trends was significant. Stover yield remained relatively constant at all N levels. In the case of HRC x HY, unhusked ear, husked ear and shelled grain yields also decreased with increased N, whereas stover yield and 1000 grain weight increased as the level of N was raised. As with WD, none of the trends associated with N were significant. Although slight, the general decline in yields of WD and HRC x HY at increasing N levels may be due to increased competition for solar radiation and to increased susceptibility to lodging at high N because of increased succulence. Also, the plant population may have been sufficiently high to cause mutual shading of plants which could have depressed growth and yield at the higher N levels.

Crop III

Crop III was planted on February 23, 1971 and harvested on June 28, 1971, and thus had a growing period of 126 days. The effect of V, N and their interaction on days to 50% tasseling, stover yield and total dry matter yield of WD and HRC x HY were not significant (Appendix C, G).

Days to 50% silking, stalk height, unhusked ear, husked ear and shelled grain weight of WD and HRC x HY were significantly different (Table 6, Appendix G). The mid-silking stage was reached by WD about 2 days earlier than HRC x HY. Whereas average stalk height was greater for HRC x HY than WD, the latter produced a significantly greater unhusked ear yield. However, the 1000 grain weight of HRC x HY was much greater than that of WD (Table 6). In all four cases, the effects of N and V x N interaction were non-significant.

In addition to highly significant varietal differences in husked ear and shelled grain yields (Table 6, Appendix G), N level also significantly affected these parameters of crop growth. Shelled grain yield increased as N level was increased from 112 to 224 kg/ha, and then declined at the highest N level. The V x N interaction was significant in the case of husked ear yield. An examination of the data of Appendix C shows that N had little or no effect on any yield parameter for WD. However, most yield components of HRC x HY increased with N to 224 kg/ha and then declined, in some cases significantly, as N was increased to the highest level. The decrease of HRC x HY yield at the highest level of N was probably due to increased vegetative growth which resulted in mutual shading of plants. Generally, there was a slight but non-significant trend towards increased stover, unhusked ear and total dry matter yields of WD as N level was increased. The 1000 grain weights at the two lower N levels were nearly identical but was somewhat heavier at the highest N level. The effect of N on

Table 6

Effects of Variety and Nitrogen on
Aspects of Crop Development and Yield[a]

(February 1971 - June 1971)

	Variety[b]	
	WD	HRC x HY
Days to 50% Silking	70[a]	72[b]
Stalk Height (cm)	213.4[b]	219.7[a]
Unhusked Ear Yield (kg/subplot)	5.61[a]	3.87[b]
Husked Ear Yield (kg/subplot)	4.74[a]	2.84[b]
Shelled Grain Yield (kg/subplot)	3.96[a]	2.30[b]
1000 Grain Weight (gm)	316.19[b]	361.15[a]

	Effect of N (kg/ha)[b]		
	112	224	448
Shelled Grain Yield (kg/subplot)	5.68[c]	6.98[a]	6.12[b]

	V x N Interaction[b]					
	WD			HRC x HY		
	N Level (kg/ha)					
	112	224	448	112	224	448
Husked Ear Yield (kg/subplot)	4.56[a]	4.80[a]	4.86[a]	2.54[c]	3.59[b]	2.39[c]

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[a] Values were averaged over three N levels.

[b] Means followed by the same letter were not significantly different from each other while those followed by different letters were significantly different at the 0.05 level of probability using the Bayes lsd test.

1000 grain weight was significant at the 10% level.

Crop IV

This crop was planted on June 10, 1971 and harvested on October 5, 1971. The effects of V, N and their interaction on stover, unhusked ear, total dry matter, husked ear and shelled grain yields were not significant. There were significant differences between WD and HRC x HY in the number of days to 50% tasseling and silking, stalk height and 1000 grain weight (Table 7, Appendix H). HRC x HY tasseled about a day sooner, but silked a day later than WD. HRC x HY was also taller and produced heavier grains than WD. N and the V x N interaction were not significant.

1000 grain weight increased slightly as N level was increased, while changes in other yield components of WD were smaller and inconsistent (Appendix D). Where trends in data existed for HRC x HY, yield generally showed small increases as N level was increased. The lack of any consistent and significant increases in growth and yield suggest that residual N in the soil was high enough to completely meet crop requirements.

Seasonal Effect on Corn Growth and Yield

The number of days to 50% tasseling and silking for WD and HRC x HY at the four planting dates is shown in Table 8. Statistical analyses were completed only on growth and yield factors within, and not between crops, because no seasonal replication was obtained. Daylength at the time of planting was essentially identical for Crop I and IV. Crop II and III had similar daylengths at planting time but the daylengths for these two crops were almost three hours shorter than those

Table 7

Effects of Variety on Aspects of Crop Development and Yield[a]

(June 1971 - October 1971)

	Variety[b]	
	WD	HRC x HY
Days to 50% Tasseling	61	60
Days to 50% Silking	70	71
Stalk Height (cm)	195.6	211.4
1000 Grain Weight (gm)	329.59	353.97

---

[a] Values are averaged over three N levels.

[b] All varietal means were significantly different from each other at at least the 0.05 level of probability.

Table 8

Number of Days to 50% Tasseling and Silking at Four Planting Dates[a]

Planting Date	Variety	Days to 50% Tasseling	Days to 50% Silking
June 16, 1970	WD	61	64
	HRC x HY	60	66
October 14, 1970	WD	67	71
	HRC x HY	67	78
February 23, 1971	WD	63	70
	HRC x HY	63	72
June 10, 1971	WD	61	70
	HRC x HY	60	71

[a] Values were averaged over three N levels.

of Crop I and IV. At tasseling and silking, Crops I, III and IV had daylengths which were nearly identical (Table 9).

The number of days to 50% tasseling was shortest during the summer plantings (Crops I and IV) and days to tasseling were similar for both varieties. Tasseling was delayed two to three days for the spring planting period (Crop III), a period when daylength and solar radiation were both increasing (Table 2 and 9). However, solar radiation was still about 33% below the levels prevailing during the summer. Tasseling was delayed 6 to 7 days relative to the summer plantings for Crop II. The delay in tasseling can probably be attributed to the almost 60% reduction in average daily solar radiation which occurred during the fall and winter. However, daylength decreased by almost two hours (Table 9) and average daily temperature was 2.5 C cooler during that period. All of these factors could delay the rate of vegetative growth and/or the development of reproductive structures.

The data for days to silking (Table 8) suggest a variety by environment interaction since the varieties responded differently at the different planting periods. WD consistently silked earlier than HRC x HY but the difference ranged from one day for Crop IV to seven days for Crop II. Relative to Crop I, silking date for WD was delayed 6 to 7 days to Crops II, III and IV. Because water was supplied by irrigation and solar radiation was 14% higher for Crop IV than for Crop I, the delay in silking for both varieties for Crop IV relative to Crop I suggests that temperature has a profound effect on ear initiation and development. Temperature averaged 0.5 C higher for Crop I than Crop IV while daylengths for the two crops were essentially

Table 9

Daylength[a] During Various Stages of Crop Growth

	Crop I		Crop II		Crop III		Crop IV	
At Planting	(Jun. 16)	13:26	(Oct. 14)	11:41	(Feb. 23)	11:37	(Jun. 10)	13:24
At 50% Tasseling	(Aug. 15 - 16)	12:52	(Dec. 20)	10:50	(Apr. 27)	12:51	(Aug. 09 - 10)	12:57
At 50% Silking	(Aug. 19 - 21)	12:48	(Dec. 24 - 31)	10:51	(May 04 - 06)	13:00	(Aug. 19 - 20)	12:47

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[a] The number to the left of the colon indicates hours; the number to the right of the colon indicates minutes.

identical. Yield data (see following discussion), however, suggest that some unmeasured factor was responsible for the observed variation in days to silking.

Villanueva (1971) conducted a study of the effects of V and date of planting adjacent to the study reported here which included HRC x HY. He found that days to mid-tasseling of WD decreased from 55 to 54 to 53 days, while days to 50% silking increased from 60 to 61 to 73 days as planting was delayed from May to June to September at Waimanalo. His data showed that days to 50% tasseling and 50% silking for HRC x HY decreased from 56 to 53 days and 60 to 56 days, respectively, as planting date was changed from May to July. However, tasseling and silking of HRC x HY were delayed from 53 to 55 days and 56 to 63 days as planting was delayed from July to September. Generally, Villanueva's data show that days to silking and tasseling for WD and HRC x HY were less than the days required in this study. The reason for this is not known but may be due to the high residual N in the test area used for this study, which, in turn, may have retarded the rate of reproductive development of the crop.

Stalk heights of the summer and winter plantings could not be compared because of damage to the October crop. Stalk heights for the two summer (Crops I and IV) plantings were quite different (Table 10). Stalk heights of Crop IV were 23 and 14 cm shorter for WD and HRC x HY, respectively, than those of Crop I. The stalk height results for Crop III and IV are also peculiar. Solar radiation and air temperatures were lower for Crop III than Crop IV yet stalk height was greater for Crop III. The effect of soil characteristics cannot be ruled out since

Table 10

Seasonal Differences in Stalk Height, Shelled Grain Yield, Total Dry Matter Yield and Grain/Stover Ratio[a]

		Crop I	Crop II	Crop III	Crop IV
Stalk Height (cm)	WD	219.11	---	213.4	195.6
	HRC x HY	225.9	---	219.7	211.4
Shelled Grain Yield (kg/ha)	WD	6,277	872	6,320	3,907
	HRC x HY	4,189	207	3,662	3,710
Total Dry Matter Yield (kg/ha)	WD	19,864	5,454	19,348	14,883
	HRC x HY	18,216	5,810	17,626	15,027
Grain/Stover Ratio	WD	0.46	0.19	0.48	0.36
	HRC x HY	0.30	0.04	0.26	0.33

[a] Values were averaged over three N levels.

Crops I and III were grown in one area while Crops II and IV were grown in a similar adjacent area.

Shelled grain yields of HRC x HY (Table 10) were similar for Crops I, III and IV but generally were lower than WD. WD had high yields for Crops I and III but yield declined approximately 40% from Crop III to Crop IV. There is no apparent explanation for the decline. Yields of both varieties were extremely low for Crop II. This was the result of the winter rains and winds which flattened much of the crop. Total dry matter yields (Table 10) were high for the two summer plantings and the February planting, but decreased drastically for the winter planting. The sharp reduction in yield for Crop II was a direct result of the rains and heavy winds which caused extensive lodging and rapid decomposition of plants in the field. There is no obvious reason for the yield decline from Crop III to Crop IV since air temperatures for the two crops were similar and, as mentioned previously, solar radiation was higher for Crop IV than for Crop III. The grain/stover ratio (Table 10) shows that WD was more efficient in converting photosynthate to grain than was HRC x HY. An interesting result is the decline in the ratio for WD from Crop III to Crop IV while the grain/stover ratio of HRC x HY increased from Crop III to Crop IV.

Effect of Variety, Nitrogen and Their Interaction on the Nutritional Quality of Corn Grain

Protein Content

The protein content of WD and HRC x HY corn grain at the three N levels and four planting dates are presented in Table 11. Standard deviations for the data were calculated because of variability in the

Table 11

Effects of Variety and Nitrogen Fertilization on Percent Protein[a] in Corn Grain

Planting Date	Variety	N Fertilization Level (kg/ha)					
		112		224		448	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
June 1970	WD	7.39	0.69	7.69[b]	0.22	7.33[b]	0.16
	HRC x HY	7.61[b]	0.45	7.58	0.21	7.33[b]	0.45
October 1970	WD	7.39	1.09	7.44	0.45	8.27	0.68
	HRC x HY	8.30	0.63	8.55	0.61	8.69[c]	----
February 1971	WD	6.30	0.30	6.00	0.75	6.83	0.44
	HRC x HY	6.55	0.43	6.86	0.26	7.36	0.22
June 1971	WD	7.28	0.13	7.42	0.08	7.38	0.35
	HRC x HY	6.99	0.65	7.41	0.15	7.52	0.33

[a] Total N x 6.25.

[b] Only three samples were available due to destruction of grain by rats.

[c] Only one sample was available due to seedless ears.

S.D. = standard deviation.

number of samples available for analysis. None of the means were significantly different from each other as measured by Student's t-test. For the June 1970 crop, the variability in sample number resulted when a rat chewed through plastic vials in which the ground corn grain was stored. In addition to the grain consumed by the rodent, the spilled grains were intermixed and the various treatments could not be distinguished. As explained earlier, the variability in sample number for the October 1970 crop was due to seedless ears.

The protein content of HRC x HY grain was higher than that of WD (Table 11) for the October and February planting dates. There was no consistent increase in protein content as level of applied N was increased in the case of WD. However, there was a tendency for percent protein to rise with increased N in the case of HRC x HY at all plantings except the June 1970 crop. The data of Olson et al. (1976) suggests this would be an expected result even though no significant yield increase resulted from the added N. Protein content of grain from the June 1970 and June 1971 plantings were similar and were intermediate between the higher levels of the October 1970 planting and lower levels of the February 1971 planting. The difference between the lowest and highest crude protein content was only about 2% for both WD and HRC x HY. Protein content of WD ranged from a low of 6.0% to a high of 8.2% over the entire planting season, while the range for HRC x HY was 6.55% to 8.55% (Table 11). Sauberlich et al. (1953) studied 19 corn varieties and found a variation in corn grain protein content of 6.8% - 8.2%. They showed that low (27 kg/ha) and high (94 kg/ha) N fertilization resulted in correspondingly low (6.8% - 8.2%) and high (9.3% - 12.0%)

protein content. Doty et al. (1946) found a variation in corn grain protein content of 7.5% - 11.9%; Wolfe and Fowden (1957) found a range of protein content of 8.2% - 10.3%. Olson et al. (1976) found that residual mineral N exerts a large influence on grain protein percentage and protein yield of corn. Protein percentage was found to vary from 6.5% to about 9% and increased with residual and applied N. They found indications that protein yield is or would be maximized with about 300 kg/ha N available under irrigated conditions. About 40 kg of protein was produced with an added 60 kg N above that required for maximum grain yield. The protein contents for the two Hawaiian varieties used in this study did not respond to N fertilization to the same degree as the mainland varieties. Also, protein percentages and thus protein yields were low, when compared with mainland varieties at rates of N where a yield response was not measured.

Amino Acid Composition

Because amino acid analysis is a very time consuming and differences in corn grain protein content were small, only a small number of the samples were analyzed for soluble and total amino acids to ascertain if any consistent trends in amino acid content occurred with N level or season.

For the analysis of soluble amino acids, grain samples from the lowest (112 kg/ha) and highest (448 kg/ha) N levels were analyzed for both varieties and all four planting dates (Table 12 and 13), thus permitting broad comparisons of the effect of N level on amino acid composition. Analysis for total amino acids was conducted on the grains of WD from the June 1970 and October 1970 plantings. These two planting

Table 12

Soluble Amino Acid Content of WD Grain (ppm Amino N)[a]

	Amino Acid	June 1970		October 1970		February 1971		June 1971	
		N Level (kg/ha)							
		112	448	112	448	112	448	112	448
1.	Cysteic Acid	0.29	1.10	0.70	0.74	0.55	0.72	2.32	0.28
2.	Aspartic Acid	1.17	10.47	6.39	6.25	6.04	6.39	3.39	1.72
3.	Threonine	7.58	10.11	5.55	4.10	3.56	4.46	10.88	6.94
4.	Serine	9.41	0	26.77	8.81	17.21	20.40	28.48	21.75
5.	Glutamic Acid	22.02	16.04	16.44	12.31	5.27	8.20	22.33	17.83
6.	Proline	4.67	4.19	0.70	0.32	2.93	2.73	2.69	11.51
7.	Glycine	6.27	5.32	7.79	3.10	6.09	6.88	7.97	4.77
8.	Alanine	26.28	25.20	33.97	11.52	20.44	30.77	28.54	21.92
9.	Valine	2.62	2.42	3.45	1.19	6.12	6.44	4.52	3.60
10.	Cystine	0	0	1.38	0.87	1.76	1.28	0	1.00
11.	Methionine	0	0	0.22	0.31	0.53	0.44	0.70	0.24
12.	Isoleucine	0.81	0.90	1.05	0.51	2.06	2.16	1.23	0.80
13.	Leucine	0.03	1.06	1.58	0.60	2.88	2.70	1.37	0.66
14.	Tyrosine	0	0	0	0	0	0	0	0
15.	Phenylalanine	2.82	1.60	3.48	1.06	5.93	5.26	5.97	2.07
16.	Gamma Amino Butyric Acid	1.73	1.26	1.38	0.51	2.55	2.37	3.07	2.17
17.	Lysine	2.32	2.76	3.59	2.40	4.61	4.07	4.34	3.18
18.	Histidine	4.28	3.11	5.03	10.25	3.37	3.16	4.88	2.39
19.	Arginine	13.61	12.87	16.53	11.14	22.90	20.31	19.90	14.34
	Total	105.91	98.41	136.00	75.99	114.80	128.74	152.58	117.17

[a] Based on extraction from 15 g of corn grain.

Table 13

Soluble Amino Acid Content of HRC x HY Grain (ppm Amino N)[a]

	Amino Acid	June 1970		October 1970		February 1971		June 1971	
		N Level (kg/ha)							
		112	448	112	448[b]	112	448	112	448
1.	Cysteic Acid	1.07	0.50	0.76	---	1.51	0.41	0.60	0.63
2.	Aspartic Acid	15.26	0.49	5.89	---	17.55	7.28	4.08	6.78
3.	Threonine	1.55	2.77	2.79	---	8.68	3.84	9.89	8.57
4.	Serine	9.46	7.83	9.08	---	46.77	20.23	36.78	37.82
5.	Glutamic Acid	0	13.53	3.29	---	6.35	3.98	25.64	18.41
6.	Proline	1.06	1.91	0.52	---	2.98	1.84	3.04	2.76
7.	Glycine	4.85	4.33	3.13	---	8.97	5.86	8.01	9.80
8.	Alanine	23.00	21.85	17.00	---	56.64	5.88	42.06	45.14
9.	Valine	3.81	3.61	6.09	---	21.27	8.10	7.07	8.10
10.	Cystine	0	0	4.31	---	5.35	0	0	0
11.	Methionine	0	0.23	0.56	---	0	1.83	0.93	1.38
12.	Isoleucine	0	1.26	1.76	---	0	2.67	1.81	2.17
13.	Leucine	1.33	1.23	3.26	---	0	3.36	1.39	2.74
14.	Tyrosine	0	0	0	---	4.67	0	0	0
15.	Phenylalanine	0	3.05	2.91	---	15.11	4.28	6.07	7.22
16.	Gamma Amino Butyric Acid	1.69	1.20	1.87	---	0	2.18	3.52	3.82
17.	Lysine	0	2.64	2.29	---	0	3.91	5.08	5.92
18.	Histidine	4.29	3.48	1.23	---	0	5.12	9.89	12.20
19.	Arginine	3.23	15.35	11.96	---	30.69	21.20	24.88	25.63
	Total	70.60	85.26	78.70	---	226.54	101.70	190.74	199.00

[a] Based on extraction of 15 g of corn grain.

[b] No data due to seedless ears of corn.

dates were chosen because they represented the climatic extremes for the study.

The soluble amino acids were presumed to be extracted primarily from the embryo tissue of the corn grain. Serine, glutamic acid, alanine and arginine were consistently higher than the other amino acids in the soluble component, but the variability from sample to sample was large both within and between crops. Except the Crop III, there was a tendency for total soluble amino acids to decrease with increasing N for WD while no consistent trends were observed for HRC x HY. However, because of the large variation, it is doubtful if any of the differences were significant. The lack of trends may also be due to nonreproducibility of the instrument. The instrument is old and many problems were encountered during the course of the analyses. It is not possible to compare these results with those of others since all other studies involved some hydrolysis of the soluble components while none was done in this study.

The amino acids present in greatest quantity in protein was glutamic acid followed by arginine, leucine, alanine and glycine. Phenylalanine, gamma amino butyric acid and arginine were the only amino acids to show any consistent trends with level of N. Levels of these three amino acids consistently decreased as N fertilization level was increased from 112 kg/ha to 448 kg/ha (Table 12). Tyrosine was absent or present in too small a quantity to be detected. The other amino acids increased or decreased without a distinguishable pattern as N level was increased for the four planting dates. Lysine tended to decrease for the October 1970, February 1971 and June 1971 plantings; it increased during the June 1970 planting. Wolfe and Fowden (1957) also found large variations in amino acid composition. They attributed differences to partial destruction of some amino acids due to the normal hydrolyzing procedure of using hot mineral acids and to incomplete hydrolysis of less purified protein to amino acids.

Total amino acid content of WD was much larger than the soluble amino acid content (Table 14) due to the fact that soluble amino acid procedure extracts only a small percentage of the total amino acids present in the grain. As a whole, for the June 1970 crop, the amino acids generally increased as the N fertilization level was increased from 112 kg/ha to 448 kg/ha. In the October 1970 planting, the concentration of ten amino acids decreased, while eight increased with increasing levels of N. Glutamic acid, proline, leucine, phenylalanine and gamma amino butyric acid increased during both summer and winter plantings. Cystine and aspartic acid decreased during both planting dates and tyrosine was not detected. Lysine content increased from 426.09 to 488.24 ppm amino N during the June 1970 planting and decreased from 662.92 to 448.66 ppm during the October 1970 planting.

It is very difficult to make comparisons between the amino acid values obtained in this study and data reported by others. Wolfe and Fowden (1957) found it necessary to extract protein from corn grain prior to determining amino acid composition of the protein. In this way they were able to account for 96% of the N of the grain in amino acids. However, there is little correspondence between their data and those of Sodek and Wilson (1971) who also determined the amino acid compliments of protein extracted from normal and high-lysine

Table 14

Total Amino Acid Content of WD Grain (ppm Amino N)[a]

	Amino Acid	June 1970 Planting		October 1970 Planting	
		N Fertilization Level (kg/ha)			
		112	448	112	448
1.	Cysteic Acid	23.14	21.92	21.62	20.26
2.	Aspartic Acid	1,152.67	135.21	1,446.94	1,323.18
3.	Threonine	.312.64	333.88	386.79	221.56
4.	Serine	551.87	599.93	654.01	447.37
5.	Glutamic Acid	3,109.21	3,381.22	3,257.95	3,507.64
6.	Proline	25.18	35.24	14.98	22.22
7.	Glycine	630.19	877.65	974.44	811.36
8.	Alanine	969.34	830.10	982.80	1,025.11
9.	Valine	242.91	118.92	357.29	377.92
10.	Cystine	89.32	118.92	125.85	100.32
11.	Methionine	222.61	143.86	131.38	135.74
12.	Isoleucine	195.57	198.05	205.67	185.27
13.	Leucine	1,099.14	1,365.84	1,143.79	1,321.85
14.	Tyrosine	0	0	0	0
15.	Phenylalanine	245.45	297.24	295.30	311.96
16.	Gamma Amino Butyric Acid	332.29	384.61	376.42	401.20
17.	Lysine	426.09	488.24	662.92	448.66
18.	Histidine	557.68	705.37	833.56	754.55
19.	Arginine	1,289.57	1,719.77	1,821.69	1,337.47

[a] Based on hydrolysis of 2.5 g of corn grain.

corn grain. The lack of uniformity of data in the literature and the data presented here suggests that there is need for a systematic study of the amino acid content of corn grain protein.

CONCLUSIONS

1. The three levels of N did not affect the rate of growth (days to 50% tasseling, days to 50% silking and stalk height) of either WD or HRC x HY, regardless of time of planting.
2. HRC x HY tasseled sooner than WD and tended to be taller, although not consistently throughout the four plantings.
3. Both tasseling and silking rates were affected by variety. To a lesser extent, HRC x HY tasseled earlier than WD during the summer, and WD silked much earlier than HRC x HY at all planting dates.
4. Silking and tasseling occurred soonest when planted in the summer and were delayed as planting dates were delayed.
5. Corn yield was affected most by season. The winter planting (October 1970) produced the lowest yields (stover and grain) of the entire planting season. Yields were so low that on the basis of the data herein, it would be economically unsound to grow a winter crop.
6. Based on total dry matter yield, WD would produce slightly more than HRC x HY at Waimanalo Experimental Station.
7. The lack of effect of the three levels of N used in this experiment on growth and yield of both WD and HRC x HY would indicate that the levels of N were too high. The optimum N levels for both varieties must be below the 224 kg/ha level.

Appendix A

Effect of Variety and Nitrogen on Corn Development and Growth
(June 1970 - October 1970)

	WD			HRC x HY		
	Nitrogen Applied (kg/ha)					
	112	224	448	112	224	448
Days to 50% Tasseling	61	60	61	60	60	60
Days to 50% Silking	64	64	64	66	66	66
Stalk Height (cm)	219.8	223.6	213.9	227.8	229.6	220.3
Stover Yield (kg/subplot)	6.91	6.96	6.22	7.07	8.05	6.89
Unhusked Ear Yield (kg/subplot)	6.08	5.82	5.38	4.19	4.21	3.86
Total Dry Matter Yield (kg/subplot)	12.99	12.78	11.60	11.26	12.26	10.75
Husked Ear Yield (kg/subplot)	5.11	4.83	4.52	3.36	3.32	3.08
Shelled Grain Yield (kg/subplot)	4.07	3.97	3.77	2.69	2.68	2.51
1000 Grain Weight (gm)	331.09	314.37	330.09	343.75	324.12	310.52

Appendix B

Effect of Variety and Nitrogen on Corn Development and Growth
(October 1970 - February 1971)

	WD			HRC x HY		
	Nitrogen Applied (kg/ha)					
	112	224	448	112	224	448
Days to 50% Tasseling	67	67	67	67	67	68
Days to 50% Silking	70	72	72	76	78	79
Stalk Height (cm)	---[a]	---[a]	---[a]	---[a]	---[a]	---[a]
Stover Yield (kg/subplot)	2.27	2.32	2.33	3.16	3.29	3.51
Unhusked Ear Yield (kg/subplot)	1.22	1.11	1.01	0.42	0.40	0.15
Total Dry Matter Yield (kg/subplot)	3.49	3.43	3.34	3.58	3.69	3.66
Husked Ear Yield (kg/subplot)	0.99	0.95	0.73	0.31	0.25	---[a]
Shelled Grain Yield (kg/subplot)	0.57	0.57	0.50	0.23	0.16	---[a]
1000 Grain Weight (gm)	222.74	251.08	261.40	286.22	298.03	---[a]

[a] Data were unavailable due to damage by rainstorms.

Appendix C

Effect of Variety and Nitrogen on Corn Development and Growth
(February 1971 - June 1971)

	WD			HRC x HY		
	Nitrogen Applied (kg/ha)					
	112	224	448	112	224	448
Days to 50% Tasseling	63	63	63	64	62	63
Days to 50% Silking	70	70	70	73	72	72
Stalk Height (cm)	211.8	210.1	218.3	216.2	219.7	223.3
Stover Yield (kg/subplot)	5.97	6.03	7.58	7.80	6.82	6.93
Unhusked Ear Yield (kg/subplot)	5.27	5.76	5.79	4.13	4.32	3.16
Total Dry Matter Yield (kg/subplot)	11.24	11.79	13.37	11.93	11.14	10.09
Husked Ear Yield (kg/subplot)	4.56	4.80	4.86	2.54	3.59	2.39
Shelled Grain Yield (kg/subplot)	3.67	4.09	4.13	2.01	2.89	1.99
1000 Grain Weight (gm)	310.61	303.39	334.58	337.52	364.62	381.32

Appendix D

Effect of Variety and Nitrogen on Corn Development and Growth
(June 1971 - October 1971)

	WD			HRC x HY		
	Nitrogen Applied (kg/ha)					
	112	224	448	112	224	448
Days to 50% Tasseling	61	61	62	61	60	60
Days to 50% Silking	70	69	70	71	71	70
Stalk Height (cm)	196.2	190.3	200.2	210.3	214.9	209.4
Stover Yield (kg/subplot)	7.21	4.54	5.54	5.36	5.96	6.88
Unhusked Ear Yield (kg/subplot)	3.82	3.33	3.56	2.76	3.52	3.79
Total Dry Matter Yield (kg/subplot)	11.03	7.87	9.10	8.12	9.48	10.67
Husked Ear Yield (kg/subplot)	3.15	2.72	3.03	2.30	3.04	3.28
Shelled Grain Yield (kg/subplot)	2.72	2.23	2.40	1.85	2.45	2.68
1000 Grain Weight (gm)	316.95	326.96	344.87	350.21	356.85	354.86

Appendix E

Analysis of Variance[a] for Crop I (June 1970 - October 1970)

Source	Degrees of Freedom	Days to 50% Tasseling	Days to 50% Silking	Stalk Height[b] (cm)	Stover Yield (kg/subplot)	Unhusked Ear Yield (kg/subplot)	Total Dry Matter (kg/subplot)	Husked Ear Yield (kg/subplot)	Shelled Grain Yield (kg/subplot)	1000 Grain Weight (gm)
Blocks	3	4.50^{*}	14.15^{ns}	$189,639.41^{ns}$	2.14^{ns}	6.56^{ns}	4.70^{ns}	2.00^{ns}	1.14^{ns}	$3,094.11^{*}$
Treatments	5	0.40^{ns}	5.54^{ns}	$170,730.10^{ns}$	1.39^{ns}	3.62^{ns}	3.18^{ns}	3.12^{ns}	2.11^{ns}	588.37^{ns}
Variety	1	0.67^{ns}	26.04^{*}	$358,547.04^{ns}$	2.48^{ns}	16.78^{*}	6.47^{ns}	14.73^{*}	10.28^{*}	5.36^{ns}
Nitrogen	2	0.37^{ns}	0.17^{ns}	$244,689.29^{ns}$	1.80^{ns}	0.58^{ns}	3.78^{ns}	0.38^{ns}	0.13^{ns}	832.26^{ns}
V x N	2	0.29^{ns}	0.67^{ns}	$2,862.45^{ns}$	0.43^{ns}	0.08^{ns}	0.95^{ns}	0.05^{ns}	0.01^{ns}	635.99^{ns}
Error	15	1.03	5.52	146,679.84	1.63	2.72	6.57	2.01	1.51	653.20
Total	23									

[a] Numbers indicate mean square values.
[b] Values are based on a total of 36 plants.
[*] Significantly different at the 0.05 level of probability.
[ns] Not significant.

Appendix F

Analysis of Variance[a] for Crop II (October 1970 - February 1971)

Source	Degrees of Freedom	Days to 50% Tasseling	Days to 50% Silking	Stalk Height[b] (cm)	Stover Yield (kg/subplot)	Unhusked Ear Yield (kg/subplot)	Total Dry Matter Yield (kg/subplot)
Blocks	3	0.94^{ns}	0.60^{ns}	----	0.15^{ns}	0.00^{ns}	0.17^{ns}
Treatments	5	0.27^{ns}	55.04^{**}	----	1.27^{**}	0.80^{**}	0.07^{ns}
Variety	1	0.17^{ns}	247.04^{**}	----	6.10^{**}	3.75^{**}	0.28^{ns}
Nitrogen	2	0.54^{ns}	12.79^{ns}	----	0.08^{ns}	0.12^{ns}	0.01^{ns}
V x N	2	0.04^{ns}	1.49^{ns}	----	0.04^{ns}	0.01^{ns}	0.03^{ns}
Error	15	1.78	5.66	----	0.11	0.09	0.35
Total	23						

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a Numbers indicate mean square values.

b Data were unavailable due to damage by rainstorms.

** Significantly different at the 0.01 level of probability.

ns Not significant.

Appendix F (Continued)

Analysis of Variance[a] for Crop II (October 1970 - February 1971)

WD

Source	Degrees of Freedom	Husked Ear Yield (kg/subplot)	Shelled Grain Yield (kg/subplot)	1000 Grain Weight (gm)
Blocks	3	0.14^{ns}	0.11^{ns}	1,958.04^{ns}
Treatment(N)	2	0.08^{ns}	0.01^{ns}	1,602.45^{ns}
Error	6	0.05	0.03	3,146.96

HRC x HY

Source	Degrees of Freedom	Husked Ear Yield (kg/subplot)	Shelled Grain Yield (kg/subplot)	1000 Grain Weight (gm)
Blocks	3	0.09**	0.06*	461.92^{ns}
Treatment(N)	2	0.01^{ns}	0.01^{ns}	279.07^{ns}
Error	6	0.0002	0.0003	2,442.27

Combined WD and HRC x HY

Source	Degrees of Freedom	Husked Ear Yield (kg/subplot)	Shelled Grain Yield (kg/subplot)	1000 Grain Weight (gm)
Blocks	3	0.03^{ns}	0.04^{ns}	365.44^{ns}
Treatments	3	0.65^{ns}	0.19^{ns}	4,692.93^{ns}
Variety	1	1.94**	0.56*	12,193.68*
Nitrogen	1	0.01^{ns}	0.00^{ns}	1,612.02^{ns}
V x N	1	0.00^{ns}	0.00^{ns}	273.08^{ns}
Error	9	0.18	0.58	1,648.06
Total	15			

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[a] Numbers indicate mean square values.

* Significantly different at the 0.05 level of probability.

** Significantly different at the 0.01 level of probability.

ns Not significant.

Appendix G

Analysis of Variance[a] for Crop III (February 1971 - June 1971)

Source	Degrees of Freedom	Days to 50% Tasseling	Days to 50% Silking	Stalk Height[b] (cm)	Stover Yield (kg/subplot)	Unhusked Ear Yield (kg/subplot)	Total Dry Matter (kg/subplot)	Husked Ear Yield (kg/subplot)	Shelled Grain Yield (kg/subplot)	1000 Grain Weight (gm)
Blocks	3	0.28^{ns}	3.44^{ns}	186,129.70^{ns}	2.09^{ns}	0.63^{ns}	1.77^{ns}	0.58*	0.45*	491.36^{ns}
Treatments	5	1.20^{ns}	7.70*	126,877.34^{ns}	2.34^{ns}	4.37*	4.73^{ns}	5.05*	3.86**	3,633.81**
Variety	1	0.17^{ns}	32.67**	309,916.74*	2.61^{ns}	18.06**	6.93^{ns}	21.66**	16.67**	12,127.51**
Nitrogen	2	0.88^{ns}	0.88^{ns}	141,014.67^{ns}	1.40^{ns}	0.64^{ns}	0.15^{ns}	0.98*	0.88**	2,426.99^{ns}
V x N	2	2.04^{ns}	2.04^{ns}	21,220.32^{ns}	3.14^{ns}	1.24^{ns}	8.21^{ns}	0.82*	0.45^{ns}	598.77^{ns}
Error	15	1.71	2.08	65,755.35	2.22	1.18	2.54	0.16	0.12	740.26
Total	23									

[a] Numbers indicate mean square values.
[b] Values are based on a total of 36 plants.
[*] Significantly different at the 0.05 level of probability.
[**] Significantly different at the 0.01 level of probability.
[ns] Not significant.

Appendix H

Analysis of Variance[a] for Crop IV (June 1971 - October 1971)

Source	Degrees of Freedom	Days to 50% Tasseling	Days to 50% Silking	Stalk Height[b] (cm)	Stover Yield (kg/subplot)	Unhusked Ear Yield (kg/subplot)	Total Dry Matter (kg/subplot)	Husked Ear Yield (kg/subplot)	Shelled Grain Yield (kg/subplot)	1000 Grain Weight (gm)
Blocks	3	1.44^{ns}	0.15^{ns}	$256,526.03^{ns}$	1.74^{ns}	0.12^{ns}	2.23^{ns}	0.07^{ns}	0.12^{ns}	$1,109.40^{ns}$
Treatments	5	1.67^{ns}	2.04^{*}	$439,945.20^{**}$	3.97^{ns}	0.61^{ns}	6.70^{ns}	0.51^{ns}	0.41^{ns}	$1,052.03^{ns}$
Variety	1	6.00^{*}	5.04^{*}	$1,897,048.38^{**}$	0.56^{ns}	0.27^{ns}	0.06^{ns}	0.05^{ns}	0.10^{ns}	$3,566.06^{*}$
Nitrogen	2	0.29^{ns}	0.54^{ns}	$13,463.40^{ns}$	2.68^{ns}	0.31^{ns}	3.20^{ns}	0.39^{ns}	0.15^{ns}	530.57^{ns}
V x N	2	0.88^{ns}	2.04^{ns}	$137,875.40^{ns}$	6.94^{ns}	1.08^{ns}	13.52^{ns}	0.87^{ns}	0.84^{ns}	316.58^{ns}
Error	15	0.84	0.69	83,116.58	9.06	0.66	7.20	0.60	0.45	440.00
Total	23									

[a] Numbers indicate mean square values.
[b] Values are based on a total of 36 plants.
* Significant at the 0.05 level of probability.
** Significant at the 0.01 level of probability.
ns Not significant.

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